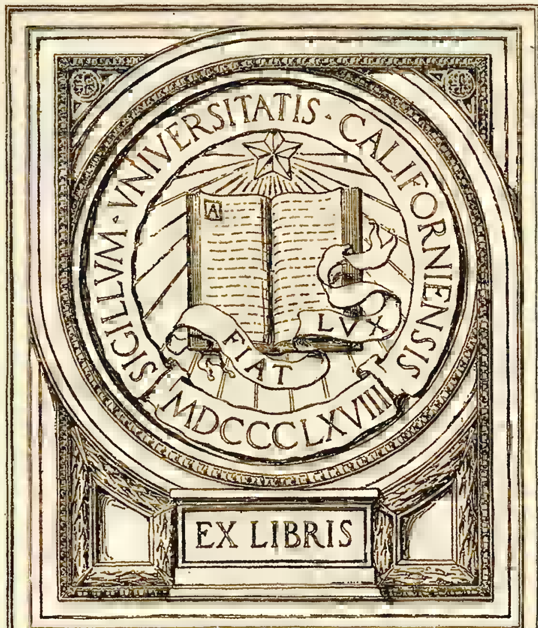
CALIFORNIA

BOARD OF DIRECTORS OF DRAINAGE DIST. NO. 1.

1880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REPORT

OF THE

Board of Directors of Drainage District No. 1,

SHOWING

PROGRESS OF WORK TO JANUARY 1, 1881.

REPORT.

OFFICE OF DRAINAGE DISTRICT NO. 1,
SACRAMENTO, December 20th, 1880.

To his Excellency GEO. C. PERKINS, *Governor of the State of California:*

In compliance with the provisions of section four of an Act of the Legislature of the State of California, entitled "An Act to promote drainage," approved April twenty-third, eighteen hundred and eighty, the Board of Directors of Drainage District No. 1 respectfully submit to your Excellency a report of their proceedings by virtue of the powers conferred upon them, including the amount of work performed and the amount of money expended.

Drainage District No. 1 embraces practically all of that portion of the State of California drained by the Sacramento River and its tributaries.

The seventh section of the Act to promote drainage, provides that "after the formation of any territory into a drainage district, the State Engineer, as soon as practicable, after proper surveys have been made, shall submit to the Board of Directors of the district, plans, specifications, and estimates of the cost of the works necessary in said district, in order to secure a proper system of drainage therefor."

After the report of the State Engineer; as aforesaid, is made, the Board is requested to adopt, amend, or reject the whole or any portion of the plans presented, or to refer them back to the State Engineer for further report. After the adoption of plans and specifications, the Board is required to advertise for thirty days for proposals before any contract for work embraced in the plans can be let. This Board was appointed on the tenth day of June of the current year. The area of the district being so great, the magnitude of the interests involved so stupendous, and the labor to be performed by the State Engineer so extensive, that although the utmost diligence was exercised by that officer and his assistants, the plans and specifications could not be completed so as to enable us to let contracts prior to the tenth day of August.

The following reports of Wm. Ham. Hall, State Engineer—and furnishing the basis of our actions—will, we think, convey an adequate idea of the problem to be solved.

THE WORKS OF DRAINAGE FOR THE SACRAMENTO VALLEY.

SACRAMENTO, June 25th, 1880.

Honorable Board of Directors, Drainage District No. 1:

GENTLEMEN: You have been called upon to carry forward such works of drainage as may be practicable and deemed necessary for the territory now known as Drainage District No. 1, and I, as State Engineer, am required to propose plans for and supervise the execution of these works.

The report to the State Drainage Commission.

The circumstances and views which have led to and governed in the formation of this district, are set forth in a report made by myself to the State Board of Drainage Commissioners, under date of May twenty-sixth, eighteen hundred and eighty, and which has been published, together with a copy of the record of the minutes of the proceedings of that Board, had at a meeting held on the twenty-eighth of May.

Drainage District No. 1.

Your district embraces all of the Sacramento Valley in which it will be necessary, as far as can now be seen, to execute works of drainage, except some of the low lands in the delta which is common to the San Joaquin as well as the Sacramento River.

The report to the Legislature.

In a general way, the drainage of this district—the Sacramento Valley—has been discussed by me in Parts II and III of my report to the Legislature, under date of January tenth, eighteen hundred and eighty. To avoid much repetition of argument in detail, I shall herein only briefly summarize the practical conclusions at large on this topic, and ask your attention to the papers referred to, for the discussions which have led to them. The broad facts in the case are as follows:

Facts concerning the rivers.

First—Generally, throughout its course, the channel of the Sacramento River as the main drain, and that of the Feather as its chief auxiliary, in their present condition, are incapable of affording passage for the waters of ordinary flood volume without subjecting a large portion of the great low-land basins and island swamps to inundation.

Second—The regimen of the Sacramento River is bad; its channel is of very uneven capacity in proportion to the demand for waterway, in the succeeding great divisions thereof, besides having serious local obstructions to flood flow.

Third—These defects, general and local, have, in a degree, always existed, but they have been largely developed of late years from causes still present or at work. The detritus from the mines is filling the lower Sacramento River and its principal tributaries, and an injudicious location of levees has unduly limited the width of flood waterway at important points and for long stretches of channel.

Preservation of the rivers.

It is desired to preserve these river channels. By the passage of the law under which we are called upon to act, the State has signified her realization of the importance of thus fostering the interests more directly affected by their deterioration, as well as those dependent upon the causes which in great measure produce this result.

The Act to promote drainage.

It is the object, as I understand the measure, to *promote drainage*—as the title of the Act implies—in accomplishing which it is necessary to do away, as far as possible, with the evil results of the flow of detritus from the mines, and to construct or develop waterway for the floods. Furthermore, it is expected that the accomplishment of this end will improve the navigation of the rivers and will facilitate the reclamation of swamp lands in the valleys adjacent, because it would be impossible to attain the primary object without doing much which will tend towards those kindred thereto.

GENERAL DRAINAGE PLANS.

Two general lines of action for the engineering solution of the river problems presented are frequently brought forward. They rest respectively upon what may be termed the Conservation and the Distribution theories of river improvement.

The Outlet or Distribution treatment.

To carry away the waters of flood, it has been proposed to supplement the river waterway by the construction of an artificial channel, or channels, on the route down the valley to the bay, thus effecting a division of the waters, and, according to the arguments of the advocates of this plan, producing a lowering of flood elevations and a shortening of high water periods. This is the plan based upon the theory that the greater number of channels in which the waters run, the less will be their flood elevations—a theory which I have called the Distribution theory, because of the distribution of the waters amongst several channels.

In the report spoken of, I have discussed this plan of outlet canals, and have expressed the opinion that it would not afford the desired relief from excessive flood heights, but, on the contrary, its primary result would be to bring about a further deterioration of the channel of the main river and impair its usefulness as a flood-carrying and navigable stream. I am led to this conclusion by the results of experience had in river improvements elsewhere, the records of

which I have examined, and by the behavior of this stream itself under conditions observed during the past two years.

The conclusion rests upon the opinion now quite generally entertained by engineers, and based upon practical observation as well as sound principles, that the division of the waters of a sediment-bearing river results in the formation of bars in the channel below the points of diversion, and ultimately in the permanent contraction of the waterway in the proportion which the volume of water diverted bears to the volume formerly carried by the channel. The only exception to this rule is to be found within the influence of heavy tidal action, and where other conditions are present favorable to the tidal influence.

The Conservation treatment.

Holding this opinion, I have recommended the alternative course—a systematic treatment of the river channel itself throughout, with the view of developing its greatest possible carrying capacity, and of maintaining it in good navigable condition. This plan rests upon the idea that the greater the volume of water in a channel, the less may be, and generally is, its grade or slope, and hence a conservation of waters in a channel having a movable bottom will tend to reduce its slope and lower its flood elevations by scouring out the bottom material. This I have called the Conservation theory of river improvement.

The lower Sacramento River and its principal tributary, the Feather, have beds most readily moved by the action of the current, and the upper Sacramento has a channel which can be greatly improved by work hereafter to be discussed. Hence I have expressed the opinion, after an examination and measurement in detail, that their development can be carried forward to a stage at which capacity would be afforded for the passage of all ordinary floods; but I have said that the work must be one for a series of years, and that from the first, the great supplies of sand which are brought down the mining torrents, must be prevented from entering the larger streams of the valley.

A general plan of operations, according to the Conservation treatment, was sketched out in the report to the Legislature, heretofore spoken of, and it remains now to classify and mention the principal works which it will be necessary to prosecute, and this I now do, so far as these can be designated at present.

Some provisions in the law.

In classifying and pointing out the works which may be carried forward under your direction, I hold in view the provision of the law which stipulates that "all moneys raised * * * shall be used exclusively for the construction of dams for impounding the debris from the mines, * * * and for the rectification of river channels in which said debris flows within the drainage district," etc. (Sec. 24.)

This stipulation would seem to preclude the construction of any such work as a relief canal, and the building of levees for the protection of lands from inundations, but it does not prohibit the prosecution of any work which may be necessary for the impounding of debris or the rectification of river channels in which the debris flows. I hold that the works hereinafter designated are necessary to effect these ends, within the district whose drainage system you are called upon to improve, as I will endeavor to *show in each case.*

CLASSIFICATION OF WORKS.

Two general classes of works must be undertaken: the first, to withhold the sands from the main stream and private property; the second, to improve the channels of those streams so that they will maintain themselves, with a small amount of attention, subsequently, in the best possible condition, as flood-carrying and navigable channels. These works may be somewhat more definitely classified as follows:

Arresting the flow of the detritus—dams.

First—Works calculated to check the flow of sands into the navigable rivers from the mining streams. These will consist of dams composed of rough stone, brushwood, and gravel, or a combination of these materials, as the case may be, located and proportioned as may seem most favorable in each case.

Structures of this character should first be projected where the best conditions are presented for the test of their efficiency at a reasonable outlay of money. Other things being equal, the lower down such works can be brought on the tributary streams, the more certain they will be of accomplishing their object, and at small outlay of money; for lighter grades are found upon which to impound or rest the materials stored, longer crested dams are possible (over which the water will pour to a less depth and with less force) and less material will be left below the site unguarded or unrestrained.

The Yuba and the Bear Rivers present the best opportunities for this class of work, and the localities where it is most needed.

In a special report to be submitted concerning each of these streams, I will make recommendations and submit plans for the works which I deem advisable to undertake at once upon them.

Preventing the spread of the detritus—levees.

Second—Works calculated to guard against the spread of the waters from the mining streams, and consequent destruction of the channels in which they flow.

These will consist of levees, and those already in existence should be strengthened, raised, or protected from erosion, as may be necessary in each case, or new levees may be constructed where none are now in existence or the old ones are not worth adhering to.

The law provides that such works as are necessary for the rectification of the river channels in which said debris flows, may be constructed. Levees on each side of such streams as the Yuba and Bear Rivers, for instance, may be necessary to prevent the spread of their waters. Now the spreading of these waters results in the deposit of their sediment and the obliteration of the river channels. It is necessary, therefore, in order to rectify these channels, that the waters be not allowed to spread, hence levees are necessary; and hence, I presume, you will undertake this class of work.

Again, the Yuba and Bear River regions present the theater of most needed action, though along the shores of the Feather, also, as well as on the lower course of the American, existing levees must be maintained, if proper control is to be exercised over their waters, and the river channels preserved or improved. In a special report concerning work which should be undertaken this season, I will speak more definitely of this subject.

Checking the shoaling of the main rivers.

Third—Works calculated to guard against the further deterioration of the channels of the larger rivers, and exert an influence towards their complete rectification.

These will have for their immediate objects, (1st), the prevention of heavy bank caving, except where such may be desirable to effect some beneficial change in the stream alignment; and (2d), the closing, or partial closing, of all deep channels of escape for water from the main stream (such as the crevasses through the bank of the Sacramento River below Knight's Landing to Sacramento City), so far as these can be closed without causing other ruptures and the creation of other lines of overflow.

Bank caving—spur dikes and revetement.

The first one of the objects just mentioned, is to be attained by the construction of spur dikes of brush, stone, gravel, sand-boxes, or piling, or a combination of some of these, to deflect the current from the bank attacked, and create deposits for new bank lines. The Sacramento River above Colusa presents the field where it will be most necessary to conduct this class of work, for there are a number of points where the river channel is of exceedingly bad trend, owing to this caving of banks, and radical changes of the channel are threatened to the detriment of its uniform regimen as a whole, and consequent defeat of its rectifications—a leading object of the whole measure.

Deep outlets—gradual closure, overflow weirs.

The second object of this class of work is to be attained by entirely closing the breaks in existing levees, so far as it is safe so to do, with earth embankments, and by partially closing the remaining openings—the deeper cuts, at least—with structures of brush, timber, and gravel or stone, over which the water may pour, when it reaches a certain safe flood elevation, without damage to the structure itself.

I consider these overflow weirs an essential feature of the plan of improvement proposed, for the river from Knight's Landing to Sacramento City, and it may be necessary to apply them elsewhere along its course also. If there were means enough at command to construct at once such strong and large levees along the river, and to do such other work as would facilitate its scouring out and rectification, by the holding of all flood water, then the weirs might be dispensed with. But this would necessitate an outlay beyond the means at all likely to be at your disposal, and as the water will undoubtedly escape during floods at various points for some time to come, I propose that it shall find passage at such points and in such manner as will do least harm, and only at such times as the river channel may not be able to carry all presented to it.

Concerning the extent of this class of work to be done, the location and character of construction for the proposed weirs, I will shortly submit a special report for your consideration.

Promoting the deepening of the main rivers.

Fourth—Works calculated to cause the removal of bars in the river, where they exercise an unfavorable influence upon the uniformity of its capacity, and thus prevent general deepening by the scouring action of its current.

Several notable bars of this character and effect exist in the Sacramento River below the mouth of the Feather, and they are found, as is usual in such cases, where the bank lines are far apart, or where some irregularities of alignment in the banks exist and cause a check or eddy in the current and a deposit of sand as a result.

Removal of bars—spur dikes, parallel dikes.

Their removal is to be accomplished by the construction of spur dikes, or perhaps similar works parallel to the current—according to the circumstances in each case—of brush, stone,

gravel, or timber piling, or a combination of these, in such manner as to cause a concentration of the current upon a judicious alignment, by contracting the channel to its normal width, and guiding the water in such narrowed channel up to an elevation equivalent to a low flood stage.

I may say here, by way of parenthesis, that dredging may be required in some of the bars, but this result is not expected generally.

As in the case of the last mentioned class of works, these constitute, in my opinion at least, a most important feature in the plans to rectify the channel of the river, and, as their position in this enumeration implies, should be carried forward before the final and completed effort is made to force scouring action by altogether confining the flood waters; because a condition of channel approximating a perfect regimen for the river is essential to success in confining its flood waters, and to approach such a condition local obstructions must be removed.

Correcting the alignment of the main rivers.

Fifth—Works calculated to straighten the river channel where, by reason of sudden and irregular turns or bends, a serious check is given to flood movements, and where the slope or grade of the country is less than that through which the river generally courses.

Under the proper circumstances a channel may be benefited in this way by making sudden and sharp bends less abrupt and angular, or by opening a new channel through behind such a sinuosity of the river course, which latter works are termed cut-offs.

Where a bend is very abrupt it may be made less so. Training the current against it by the use of spur dikes constructed on the opposite shore above, crowding the current out of the opposite bay by the continuation of the series of spur dikes from above down into it, and blowing down the point from time to time to be washed away, as may be necessary, will accomplish this result.

Cut-offs—Upper Sacramento River.

To cause the complete elimination of a bend from the course of the channel, cut-offs are made by clearing the path of the proposed new channel, cutting out a canal down to near low water mark upon its route, to a width of one tenth to one fifth that of the proposed channel, and forcing the currents of floods to enter the cut by a proper arrangement of spur dikes or other guiding works if it be necessary, and from time to time gradually closing the old channel as the new one becomes efficient by washing out.

The Sacramento River, between Colusa and Butte Slough and the mouth of Feather River, is a very tortuous stream, and narrow in proportion to its dimensions above and below. The grade of the country through which it flows for this division is much less than that above. Its capacity is much less than that of the divisions above and below under existing circumstances, and this is largely occasioned by excessive bend resistance due to the sudden turns in its channel and general tortuous course.

To bring the river to a good regimen it will be necessary, in my opinion, to diminish the abruptness of the most acute turns in this part of the channel, and shorten it also, by making some cut-offs. These can be carried out at a reasonable outlay of money, in a number of instances.

Prevention of cut-offs—Upper Sacramento River.

While it is necessary that the river's course should be straightened through the divisions from Butte Slough to the mouth of Feather, I hold that above Butte Slough, where the formation of cut-offs is most easy, and where they do occur naturally sometimes, all straightening of the channel should be prevented, because the river is already of much greater grade and cross sectional dimensions than it is in the division next below, where it is necessary, by making cuts and the other works spoken of, to increase its carrying capacity and thus accommodate the floods which are passed through the channel above.

Cut-offs—Lower Sacramento River.

Besides the points in the division mentioned from Butte Slough to Feather River, the only other locality where the cut-off treatment is admissible on the Sacramento River, is at the upper end of Steamboat Slough, where it is desirable to open up a new head for that channel, in the process of making it the principal line of escape for the flood waters. This subject is quite fully discussed in my report to the Legislature, and I will not say more upon it until I present the details in a special paper.

Forcing the scouring and enlargement of the main rivers.

Sixth—Works calculated to confine the waters of the river to its channel and cause an enlargement thereof by the scouring action thus brought about.

These works, of course, are levees, a complete system of which, from the highest point on the river where its waters escape into the back basins to the point where full tidal action is met at the foot of Grand Island, is essential, in my opinion, to success in the work of rectifying its channel and its final maintenance in an efficient and serviceable condition as a line of flood escape and a navigable thoroughfare.

Concentration of waters.

That the concentration and deepening of running water does increase its power to transport sediment, and thus bring about an enlargement of its channel, if the bed and banks thereof are of a character to be at all readily moved, engineers and others who study such matters are well agreed.

The confining of a greater body of water over the bed of the Sacramento River will undoubtedly cause its enlargement by the process referred to; and if local obstructions are removed in the manner heretofore spoken of or in any manner which may be necessary, this enlargement will go on so long as the waters are held in and the bottom is found to be of the character known to exist generally throughout the lower river, until the stream is much increased over its present dimensions; *provided*, that the extraordinary flow of sands by which the waters are now overloaded is checked in the mining tributaries.

The levee system.

It is frequently urged in argument against the levee system of river improvement, that the prevention of overflow causes the rapid elevations of the stream's bed as compared to the banks and back lands upon which the waters are prevented from spreading their sediments, and thus finally results in the overthrow of the levees, destruction of the lands, and injury to the river itself.

Although in the course of ages this result might, under the natural order of things, have been brought about by leveeing the Sacramento River, it is certainly a question of much less time, under existing circumstances, when the channel below the mouth of Feather River will be destroyed, if the whole river is not treated by the levee system; and as for the back lands, they can be no worse off than they are now in any event.

Deterioration of the Sacramento River.

This river channel is being destroyed by the sands which are rolled along its bottom, not by the fine sediments which are carried in suspension by its waters, and which only would be carried in large quantities out of it upon the back lands, if the levee were obliterated.

The escape of waters from the channel would not relieve it from the charge of solid matter which it annually receives, but would simply cause the permanent lodgment of that matter therein, whereas, by the confinement of its waters alone can the conditions be produced under which this detritus may be carried forward to the flats and marshes of Suisun Bay, where it will do less harm, for many years to come, than where it is lodging now.

We have had the low-water plane of this river raised two, three, four, and even five feet during the past twenty years. Such a rapid change was never heard of before in the history of other large rivers, and where the levee system, too, had equal scope for action. The bed of the Po, a river completely leveed, and whose waters are highly charged with sediment, has not been raised so much during the period of its recorded history. The levees of the Po may have caused a relative rise of several feet in its bed over that of its banks during the past two centuries, and so the levees of the Sacramento may ultimately have that effect. But the first effect of a complete levee system on this river, when it is brought to a good regimen and the flow of sands stopped, will be to cause a great scouring out of its bed and enlargement of its channel, and thus lower both its flood and low water planes, and many years will elapse before the effect of the levees in causing a contrary action will be felt.

The Mississippi and the Sacramento.

A river such as the Mississippi, whose great defect in capacity is due to the very shoal bars caused by caving banks and great irregularity of width, can have its waterline sufficiently lowered by the simple scouring out of these shoals to carry its floods between banks without a levee system as a necessary part of the plan.

Not so, however, with the Sacramento. We must remember that such is not the principal cause of deficient capacity in our river. Its banks are quite stable where the capacity is small; but few shoals exist to be removed, and these, although their continued presence would prevent a general improvement of the channel, are not themselves the principal cause of its inefficiency.

The Mississippi River, with a flood discharge of one million two hundred thousand to one million four hundred thousand cubic feet per second due to it, carries over or in its main bed from five sixths to nine tenths of its waters, losing one sixth to one tenth only into the swamps at high flood stage.

The Sacramento River, between Butte Slough and the mouth of Feather River, with a flood discharge of eighty thousand cubic feet per second due to it, carries through only thirty thousand, having lost into the back basins on its course nearly two thirds of its waters. There is no considerable obstruction to flood flow from shoals in this part of the river. The channel is narrow, has firm banks, and is exceedingly crooked.

The floods rise to their maximum height in the upper portion of this division next below Butte Slough, and overtop levees three or four feet in height before the water is bank high at Knight's Landing, twenty or thirty miles below.

Defects of the Sacramento River.

As before remarked, these divisions of the Sacramento River—from Butte Slough to the mouth of Feather River—are in need of something more than the sweeping out of shoals. The channel must be straightened and heavily leveed to facilitate and force its enlargement throughout.

This river is naturally too small for the amount of water that is presented to it generally throughout its course, because, for ages past, so large a portion of its volume, at time of flood, has, from local causes, escaped into the back basins, that the channel way has become contracted. The proof of this action is found in the fact that below every escape channel of note, all along its course, there is a radical diminution of average cross sectional area; and furthermore, as the water has escaped gradually over the banks all along, there is a gradual diminution in width found in going down stream through each grand division of the river, from one large outlet or tributary to the next below, until we arrive at the region below Grand Island, where the tide has full sway and its flow regulates, in a great measure, the width and depth.

The popular idea of filling the low basins.

We have frequently heard that the Sacramento River should be allowed to overflow its banks so that the low basins might become filled up. It may be remarked here, with propriety, that these basins would not fill up unless the river deserted its present course and occupied them in turn as channel ways. The river bed and its immediate banks were naturally built higher than the basins before the advance of the sands from the mines, and they would probably continue to rise more rapidly than the basins, for the sediments brought down by the waters of such streams are, for the most part, deposited immediately on the bank which is naturally overflowed, and it is only when the waters escape with force through a crevasse that the solid matter is carried far back into the basin and elevates it commensurate with the rate of elevation of the river bank and bed.

The true idea of this matter.

Thus the only way to equalize the land elevation back from the river to that along its bank would have been to levee the river and force streams of water back to the basin through channels, and there cause the deposit of their sediments.

But as the river has received this charge of sand, which cannot thus be sluiced out on to the low lands, to any great extent at least, and as the preservation of the river is the object in view and not the filling up of the basins, there is still greater necessity now for a complete confinement of the waters between levees.

I refer in the above to the Sacramento River below the mouth of the Feather, and presume that the object is to preserve and improve its channel. That this river itself could be turned into the basin which flanks it on the west, and there be made to deposit its sediment for some years to come, is quite certain; but the result would be destruction to the present channel, and the future would be altogether problematical with the land and cities below the point of turning.

Necessity for a levee system on the Sacramento and Feather Rivers.

After the other works which have been hereinbefore spoken of have been well taken in hand, the general leveeing of the river should begin. This work should be prosecuted from the upper portion of the stream downwards, in the reverse direction from that of the other principal improvements. The channel itself should be cleared of local obstructions from the lower end up, to bring about the conditions under which it will profit by the effects of leveeing and confining its waters, and then this forcing should commence at the upper end.

The first leveeing that is undertaken, therefore, other than that necessary to equalize banks along the river generally and close gaps as before explained, should be from Chico Creek to Butte Slough.

In my report to the Legislature, already referred to, will be found some general suggestions for the disposition of the levees along this part of the river as well as through other divisions. In special reports on the subject, hereafter to be submitted, the matter will be treated more in detail.

OTHER WORKS.

I have now classified the works which it is essential should be carried forward for the rectification of the main rivers of this valley, and have indicated, in a general way, the localities where they are to be undertaken, and the order of their proper progress.

In addition to these it may be necessary, as time goes on, to execute other works, some of them of considerable magnitude, in order to relieve the large rivers of the load of silt which is brought to them, and insure their continued improvement, as well as to otherwise dispose of flood waters, if the drainage of the valley is to be made complete.

Diversion of tributaries to deposit detritus.

For instance, although the Sacramento River itself cannot with propriety and safety be turned into any of the low basins which flank it, as a means of disposing of the sands, the case

may be different with several of its tributaries, notably the American and the Bear Rivers, which might be led to deposit their sands in the low basin lying between the two on the east side of the Sacramento. Indeed, they both do so now in a degree, and during the past season the Bear River has shown a strong disposition to turn to the south altogether and desert its former mouth into the Feather for an outlet into the basin mentioned.

An examination in detail of the practicability and cost of thus disposing of the sands of these two troublesome tributaries will be made under my direction during the present season, and will form the subject of a special report at a later date.

Diversion of the Coast Range Creek flood waters.

And still again, the disposal of the waters of Putah and Cache Creeks, which flow into the Yolo basin, is an essential part of a complete system of drainage for this district, if not absolutely a necessary operation in the rectification of the main river channels. This project is discussed in Part II of my report to the Legislature, and I invite your attention to the views there advanced.

In my opinion, these creek waters should be turned through a high grade canal over the Montezuma hills, to an independent outfall in the slough north of Suisun Bay. By this means only can the great accumulation of water in the Yolo basin be prevented, the levees of the river be maintained and rendered efficient at reasonable outlay, and the success of the drainage of the valley be rendered complete.

GENERAL REVIEW OF THE RIVER TREATMENT PROPOSED.

Glancing over what has been said in this report, and in that made to the Legislature in January, it will be found that I have advocated the Conservation treatment in the improvement of the main rivers of this valley; that I propose to bring the channels to a good regimen—even capacity to do the duty required—by straightening them where necessary and admissible, by scouring out shoals where these exist, particularly in the lower river, by training the current to destroy great eddies, and by preventing the local escape of flood waters in large volume, and to supplement its present capacity by raising levees which will themselves form a larger channel-way and force the enlargement of that already existing by the scouring action of the confined waters.

A system of levees necessary.

And I hold that a levee system is necessary to preserve the existing channels of the Sacramento and Feather Rivers and to accomplish their rectification.

If these channels were more nearly proportioned in size to the volume of water which comes down the valley, and like many other streams, were deficient in capacity merely because of local obstructions, such as extended bars, their rectification could be accomplished without the levees. But, as has been shown, such is not the case, and we can only accomplish the object through the medium of a levee system.

Could we sweep out of existence all levees now standing along the Sacramento and Feather Rivers, the floods would spread into the back basins at many places, and there, finding shorter lines of escape from point to point on the rivers, would pursue these routes, robbing the channel in some of its divisions of the waters due to it and necessary to preserve its size, and gorging the channel with more than it could carry at other points.

The result would be the contraction of the existing channels in some of their divisions and the formation of new outlets or the enlargement of those already in existence, until, by the action of some great flood, the channel of the river itself would change materially. This is just what was going on before leveeing commenced here.

Now there are levees over four fifths of the route of the river within the district where their waters could naturally escape into the back basins. These levees are of very uneven height, and some of them badly located. If they are left in their present condition, and an attempt be made to improve the channels, what will be the result? Manifestly a more unfavorable one than if there were no levees at all. The waters would escape where the levees are weakest, or where there are none, and in large volume locally, as they do now in reality, and the river could not be brought to a good regimen, for there would be no control of the floods, which would leave the channel or return to it whenever opportunity offered; and without a nearly perfect regimen we can hope for no general improvement in the channel.

The object is to prevent the further deterioration of these rivers and to improve them.

The detritus lodged in the river beds must be disposed of, and the channels otherwise rectified and enlarged. It is absurd to talk of dredging them all out, as has been publicly suggested. Twenty millions of dollars would not more than free the two rivers by this process.

A portion of the sediment should be used in levee construction, but the great mass must be swept out by the river currents. This can only be accomplished by putting the rivers in condition to facilitate this action, and by a control of all ordinary floods; and a system of good strong levees is essential for this treatment.

Such a system as is necessary for this purpose, however, will not effect the complete reclamation of all the swamp lands in the great basins of the district, but of course would do much toward that end. There would still be a necessity for organized action in the reclamation districts which must continue to exist and each labor in its own behalf, while the drainage work

will be for the common good of all. This subject is more fully touched upon in a report submitted by me to the State Board of Drainage Commissioners, under date of the twenty-sixth of May, and to that paper I ask your attention.

AN ESTIMATE OF COST.

Concerning the probable cost of the works herein outlined, I can only at this time give a rough idea. To construct levees of proper size entirely anew along the Feather and Sacramento Rivers where necessary within this district, would cost in the neighborhood of three millions of dollars.

It may be said that one third of this work has been accomplished efficiently thus far, so that it could be made a part of the work of the future. We have then a balance of two millions of dollars to be expended on this class of work.

An estimate of what might be expended to advantage within the next ten years may be made, as follows:

Levee work	$2,000,000
Channel corrections, etc.	2,000,000
Storing sands	1,000,000
	$5,000,000

Fully one half of this work is such as the general government might possibly undertake for the preservation and improvement of the rivers as navigable streams, but it must be brought forward in its order with the other works, and cannot be left behind, else the whole will be a failure.

The work should be so carried on as to diminish the time of execution as much as possible; there would be economy in such a course, for they will undoubtedly cost more unless put in final condition as fast as natural action will permit.

Supposing the five millions of dollars were expended during the next ten years, I estimate that the cost of maintenance would be about two hundred thousand dollars per annum after that period, half of which would be for storage of sands and half for river works; and the general government might be expected to bear half of the expense if it pursues its present policy in river works.

The maintenance of levees, while properly remaining under the direction of the Drainage District Boards, should ultimately be paid for by the lands thus protected from inundation, and thus the State's share of the expense of maintaining her rivers in good condition will, in the future, be reduced to a small amount.

Very respectfully submitted.

WM. H. HALL,
State Engineer.

REPORT ON DAMS FOR THE STORAGE OF MINING DETRITUS ON THE YUBA AND BEAR RIVERS.

OFFICE OF THE STATE ENGINEER,
SACRAMENTO, July 6, 1880.

To the Board of Directors of Drainage District No. 1, Sacramento, Cal.:

GENTLEMEN: In the matter of constructing dams for storing mining detritus on the Yuba and Bear Rivers, I have to report now in general terms, and when further examinations shall have been made of the several sites for dams and storage ground, I will submit another report concerning the same, and recommend the adoption of a definite policy on each river.

Transportation of sediment by moving waters.

The conditions in a stream most favorable to the transportation of sediments by its waters are: (1), that it be deep in proportion to its width; (2), that it be of uniform width and grade; (3), that its channel be of good alignment, free from sudden bends; and (4), that the lines of its currents be not broken up by obstructions of any kind.

With such conditions, a rapid current, uniform in its movement throughout the several succeeding reaches and divisions of the stream, with a sharply inclined vertical velocity curve, would be produced, and the waters would have great power to transport solid matter.

Reversing these conditions in any manner, the waters drop their silicious or earthy load in a degree proportional to the extent of the reverse order produced. Thus, sediment-carrying currents may be made to deposit their sand and slimes by checking the velocity, and otherwise destroying the conditions essential to their transporting power.

This may be effected in either one of three ways: (1), increasing the width of the stream, thus reducing its depth as a direct consequence, and indirectly reducing it also by causing the raising of its bed by deposits thereon; (2), reducing the grade or slope of the stream by changing its alignment, or by raising its bed at some point by a dam; (3), breaking up the threads of its current by the introduction of pervious or partial obstructions to its flow.

The Yuba and Bear River deposits.

The Yuba and Bear Rivers have made immense deposits of gravel, sand, and slime above their confluence with the Feather, because their grades greatly diminish as they approach that stream, their waters have overtopped the low banks and spread in wide sheets over the adjacent bottom lands, and the dense growth of small timber and brushwood through which they were made to run broke up the lines of their currents.

Deposits in this manner occasioned at lower points, have served to reduce the grade for other points above, and thus, there also, filling has taken place; and still again, in the cañons the natural irregularity of regimen, and the damming up occasioned by the lower mining dumps, have made many extended reaches the storehouses of heavier detritus.

Proposed artificial deposit of detritus.

Now it is proposed to cause an increased deposit from the waters of these streams, at such points that it will not damage private property or injure the navigable main drains below.

So far as the currents of the Yuba and Bear Rivers themselves are concerned, it matters not whether they are either restored or supplemented by other deep ones, so long as the objects just expressed are attained. Indeed, the primary object being to preserve and improve the channels of the main drains or navigable streams—the Sacramento and Feather Rivers—it would seem to be advisable to avoid any immediate restoration of the channels of the tributaries; for materials washed from them must pass down into these larger rivers, and it is important to withhold all the sand that can possibly be held back, at least until such time as they—the rivers below—can have been brought to a good regimen and scoured out.

In view of this condition, I recommend that the treatment for the Yuba and the Bear be such as to retain their channels, for years to come, at least, somewhat as they now are, in wide and shallow beds; and rather encourage further deposits upon the sand wastes already formed (where this can be done without great damage to other yet uninjured property), than to cause the restoration of any deep channels through these deposits.

This treatment should be pursued until such time as it shall have been shown that the sands are stopped at higher points, and the large rivers below are, in a great measure, relieved from their filling.

Locations for and character of dams.

Within the cañons of the mountains through which the Bear and Yuba flow, it is not possible by any direct method to widen the channels. This can only be accomplished by building up their beds through the action of dams, thus effecting the double object of increased width and decreased grade above each dam.

The subject of retaining the detritus by means of stone dams within the cañons of the Yuba River was discussed by me in Part III of the report to the Legislature, submitted in January, and allusion was made to the possibility of effecting the same end by means of dams of brush and gravel at lower points on the same streams.

Further observation and thought have convinced me that the work should be commenced as low down on the streams as the detritus can be held safely, and that the dams built must at first be of the latter mentioned class.

The sands stored at lower points will themselves serve, to some extent, as dams for storage sites at points above; and furthermore, brushwood is the only material to be had at some of the sites for dams, and these structures must be built of it if at all.

A brush dam possesses the advantages of greater stability and safety on soft or sandy foundations, and great cheapness of construction.

A rock dam has in its favor the considerable advantage of the durability of its material and of stability under great floods—supposing, of course, its foundation to be secure.

Upon the wide sand flats below the cañons proper, undoubtedly brush dams should be adopted, primarily, at least; while between the high banks of the foothills, rock dams, where material is abundant, can be most conveniently built, and would have the advantage of permanence to a degree which should render their ultimate adoption advisable.

Storage below the cañons.

Were the sands stopped at the cañon mouths on the Yuba and Bear, it would still be necessary in preventing the channeling out at lower points through the sand wastes above the Feather, to lay in some low brush dams or sills, as heretofore alluded to, in order that these lower sands might not be swept down before the large rivers could receive them safely. This being the case, it will be wise to make these obstructions do the additional duty of holding more sands if possible, and hence at the lowest point where this can be done with safety, the first dams should be built.

All of the sands which will come down these streams for several years can be thus stored below the cañons proper, on lands already covered; and, by an extension of leveeing work, still greater storage capacity can be obtained over the same superfices.

Stone dams commenced with brush.

The great danger of destruction to a stone dam of the character and for the purposes it is proposed to build them on these streams, is from undercutting at its down stream edge, and in building of stone alone it is difficult and expensive to guard against this action.

With brush, however, this difficulty is much more readily met, and it is proposed to protect the stone dams by submerged brush dams at the down stream edges of their aprons. These brush dams, by raising them higher, can be made to retain a large amount of sand above them before the stone dam is commenced, and hence, again, we have sound arguments not only for the construction of the first dams low down on the streams, of brush, but for the commencement of all dams with that material.

THE STONE DAMS PROPOSED.

It may be well to consider here for a moment the principles upon which we are to proceed in the matter of constructing dams, both of brush and of stone.

Stone dams—character of.

The proposed stone dams would be massive structures of loose rubble, not coursed or hand-laid, but somewhat assorted with respect to size of pieces, as hereinafter explained, with crests ten to twenty-five feet in thickness, and long slopes both up and down stream.

For a clear idea of the problem of these stone dams, it is essential to remember that they are to be for the purpose of storing sands, and not water, and that it will not be necessary, under a proper system, to have any one of them more than twenty feet—say an average of twelve feet—in height, at any time, over the bottom immediately up stream from it. Hence the dam becomes but a facing for an upper plane of sand; it becomes filled and impermeable only by degrees, as the sands rise upon it; and the hydrostatic pressure behind it is always limited to that due to but a few feet in depth of water. Such a dam is intended to be added to each year, using the filling above as a foundation for a portion of each addition, until the structure is brought to the desired height for its site and becomes solidified with the filling against it.

Stone dams—their weak points.

If rocks of sufficient size are used, its destruction could only be accomplished: (1), by the water finding a low place in the crest, and there concentrating its force; (2), by undermining; or (3), by flanking its ends.

The mere pressure of water or shock of a flood could not overthrow a dam of this kind; so that its destruction, if ever accomplished, could only be gradual, and not a sudden catastrophe.

Ordinary care in construction and maintenance, and the use of very large stone on the crests and down-stream faces, would prevent damage from channeling down and concentration of waters at any point.

Ordinary good construction, too, will insure against the ends being flanked by the floods, for the water may be kept away from the extreme ends of the crest, and a good junction may be made with the bedrock in the faces of the hills.

On the foundation, we have the weakest line to guard.

If large rocks—say twenty tons apiece—be laid in a row on the sands across the bed of a river, such as the Yuba or the Bear, they will quickly disappear—the sands from between them will scour out, the rocks will gradually drop into the cavities produced, and will soon have disappeared almost entirely, if not quite.

If the same quantity of stone, broken to the size of ordinary river gravel, be placed in a ridge across the channel in a similar locality, it will not be undermined; the top stones will be swept off, probably, one by one, by the force of the current, and the whole ridge flattened down, in time possibly destroyed by this means, but it will not be dropped out of sight, in the sands, by the action of the current passing under it from above. If there should be considerable fall over it, and no apron or flat surface of stones below, the sands would probably be swept away from its down-stream edge, and the stones or gravel would be washed into the cavity thus formed.

Here we have a picture of the manner in which a rubble-stone dam may be undermined, either by the water running along upon the sands, by way of the spaces, between the stones that compose the structure, from above, or by the cutting under the lower edge of the structure after having passed over its crest.

Stone dams for storing detritus—principles to be observed.

Should we imagine a dam built up in thin layers, the material in each succeeding one graded in size somewhat larger than in the layer below—from the dimension of the particles of sand up to those of the great mass of rock capable of withstanding any force of water that can possibly be brought to bear upon it—we would have before us a dam totally incapable of destruction by undermining from above, because the interstices between the particles of no one layer would be sufficiently great to admit the passage of a stream of water strong enough to wash out its particles or those in the layer next below.

In the construction of stone dams to store the detritus on the Yuba and Bear Rivers we must approach this condition in their parts: the sands under the foundation must be covered so that the waters of percolation will not wash them; the rocks upon the crests must be of such great dimensions that the force of the water cannot move them, and the pieces of the intervening material must be intermediate in size.

Practical construction of stone dams.

The foundation may be secured by first depositing layers of very fine stone upon which to build; or the same object may be attained by building the stone dam upon a foundation mattress or matting of small brush, with fine stone or gravel intermixed.

Having secured the foundation from washing above, the undercutting at the toe must be guarded against.

First of all, for a considerable width below any overfall, there must be an apron to receive the shock of the waters and permit of their taking a horizontal direction in the onward flow, before reaching the movable bottom.

This apron, of course, would be most durable if constructed of stone, provided its undermining were guarded against, and to a stone dam there should be a stone apron, though one of logs or of brush and gravel might be used safely for years.

The lower edge of such an apron, of whatever material composed, unless it were of very great width and the water spread over it in a very thin sheet, would be liable to suffer from this undercutting influence, unless the transporting power of the water were broken up at that point.

Flowing over or past a hard and fast line, such as the edges of a stone or log apron would be, water almost always attacks the soft material adjacent to it, and cuts a hole or pit. On the contrary, a windrow or driftrow of brush, lodged in a current so that the waters partially pass between the branches, causes a deposit of sediment and the formation of a bar below, which works up to and finally covers in the brush itself.

By a proper construction and the use of brush on this principle, with which to finish the lower edge of the stone aprons, not only may their undercutting be prevented, but the sands may be caused to pile up where it might be supposed they would cut out.

I do not propose to consume time and space in citing instances where like effects have been artificially produced in engineering work. Suffice it to say, that the annals of modern river engineering afford analagous examples, and the working of the law upon which the result rests may be observed in nature every day, and in many places upon our own streams.

I am of the opinion, therefore, that stone dams of this character can be put upon the sand foundations in the lower portions of and at the mouths of the cañons of the Yuba and Bear Rivers with perfect safety.

Dams for storing detritus, and other stone dams.

I remark the difference in principle upon which we should proceed in laying the stone dams here contemplated, from that followed in placing stone foundations for other purposes.

In the case of the proposed rubble dams, we expect percolation through them, and only guard against the washing out of the material below by covering it in with other material, the nature or arrangement of which will not admit of the washing.

We have water highly charged with silt, which it is expected will deposit its load in the dam as the sands are rolled against it. We are not constructing to hold clear water, or to bear a heavy load.

In stone foundations for a bridge or a masonry dam, the work itself is intended to be impermeable and immovable from the commencement; the largest stones may be placed at the bottom, and it is not intended that they should move.

In the case of the proposed rubble dams, although they must be placed on good sand and gravel foundations, and not on quicksand or "slickens," settlements which will be utterly destructive to works of the other class, would not be a serious circumstance; indeed they are to be expected, and the dam's crest must be brought up to grade as well as raised, perhaps, to accomplish more storage each year.

Stone, the proper material for the future; brush, for the present.

And, in view of the fact that all dams to be used in storing this material should be as permanent as possible, I think the great mass of it in the future should be stored above stone works.

But, considering what has preceded in this paper, I am clearly of the opinion that the work should be commenced with brush structures, and possibly this brush work can be used in other ways so as greatly to cheapen the stone structures, as hereafter suggested.

THE BRUSH DAMS PROPOSED.

Concerning brush dams there is not so much to say. The illustration heretofore cited of a driftrow of brush lodged in a current, affords the idea of the simplest form of such a work, and the natural growth of brushwood and small timber over the sand flats in Yuba River and Bear River presents another excellent example of a pervious brush dam, which causes a deposit commencing below it, by breaking up the lines of the current, and thus destroying its capacity to transport its load of solid matter.

Natural brush dams.

One cannot long study the action of this growth in the localities mentioned, without being thoroughly convinced of the efficiency of the brush dams which nature thus rears in the way of the floods with their charges of sand.

It has only to be seen for the fact to be appreciated, that but a small proportion of the solid matter is carried through such an obstruction, and that it would only be necessary to close the channels intervening between the great growths of young trees, by similar obstructions, to cause an almost complete intercepting of the detritus.

Thus, were the sand-covered flats of the Yuba and Bear Rivers flanked by high plains or levees, they might be made to retain the sediment to be brought down for a number of years to come, by simply causing the sands to rest upon them on greater grades, by placing low permeable brush dams at short intervals of space in the way of the currents, and adding to them from year to year.

As it is, however, no such banks exist very far down into the plain; the time has passed when this action could have been availed of to any great extent without artificially confining the waters on the sides, and for this purpose very large levees must be now constructed, although by such means the storage room below the foothills will be increased, yet it is limited, and we must look forward to the time when it will be exhausted. When we can no longer raise the lower portion of the storage ground there will be an overfall necessary at some point—the lowest limit of the deep storage—and for that a pervious brush dam will not suffice.

There must be a firm structure down whose face water may fall, as over a stone dam, without washing out any of the material in or under it.

Impervious brush dams.

Of gravel and brush or small trees, such a dam can be readily built to a moderate height.

The main structure, in order that it may be firmly held to the sand and gravel, must be built with the tops of the trees up stream with their branches covered in and incorporated with gravel or coarse sand, by which arrangement also the butt ends are placed down stream and form the overfall face and crest of the dam.

A heavy apron, immediately below the overfall, should be constructed in similar manner; while to prevent the undercutting action from below, a lower apron must be provided with the brushy ends of the trees down stream.

We would thus have a dam as immovable as a drift tree which lodges upon a sand bank and forever forms a snag, unless removed by human agency.

Stability of brush dams.

If we consider the width to which the waters of the streams now under discussion are spread at the points where it is proposed to construct brush dams, we will realize how they will be robbed of their destructive force by being led to encounter an obstacle such as a dam in the face of the entire front of their flow.

For instance, the extreme flood discharge of the Yuba River is about fifty thousand cubic feet per second, and its ordinary flood discharge does not exceed half that amount, while its usual discharge through the Winter and Spring is about five thousand cubic feet per second.

I take the larger figure to illustrate the case: At the De Guerre dam site, the shortest proposed line of construction for a brush dam, the overfall will be about five thousand feet in length. Fifty thousand cubic feet of water per second, running at a speed of ten feet per second, will pass over a crest five thousand feet long in a sheet one foot deep, or running at the rate of five feet per second, it would pass over the five thousand foot crest two feet in depth.

In actual practice it would run at a rate according to its velocity of approach to the dam, which would make it from 1.3 to 1.7 feet deep over it.

With a stick to brace himself, a man could almost wade across the Yuba River on the crest of such a dam at the time of its greatest discharge, and could certainly do so at time of ordinary flood, provided the dam was so placed and constructed that the water approached it with nearly equal velocity at all points.

Now, a sheet of water a foot and a half deep, moving at the rate of seven feet per second, represents about the maximum moving force we have to contend against, and under such circumstances it will not be a difficult task to construct brush aprons below the dam, and so guard them as to insure against undermining.

We have examples of brush dams of comparatively slight construction in California which have long withstood the action of water running over them to an equal, if not a greater depth.

Governing the deposit of detritus.

There can be no doubt but that the gravel, sand, and much of the finer sediment brought down by these rivers can be deposited almost wherever it is desired to place them within the territory now covered by the sediments, and held there permanently by brush work only, to a height varying from one to twenty feet, in addition to the depth of detritus already in place.

The practical limit to thus disposing of this sand will be found in the leveeing to prevent the overflow of adjacent lands.

Recent river works have shown in a wonderful degree what complete control the engineer may have over the currents and their sediments, if he only study his subjects closely and seize upon local advantages.

We all know that a lattice fence forms a complete wind-break. Sands blown up from the beach are arrested and made to pile up in great dunes or ridges parallel to the water front by the construction of light wicker work or brush fences.

Works of this kind are numerous in older countries, and the experiment was successfully carried on for several seasons under my direction at the seaward end of Golden Gate Park in San Francisco.

Similar constructions which do not present enough resistance to the currents of water to be swept away or undermined by them are now used to gradually check their velocity and to force them to drop their sands—like those blown by the winds from the beach—where the engineer desires to have them rest.

Within the last two years, upon the Missouri River, near Omaha, a greater advance has been made in this class of work than was previously chronicled to my knowledge.

I here quote from a popular account of these operations, recently published in the *Scientific American*, deferring more extended notice of the official report spoken of, and the details of works, until I submit to you a special report on the improvement of the larger streams in your district.

Experience on the Missouri River.

Speaking of the Missouri River, the journal, after describing the action of the stream at certain points, says:

"To keep the river within regular bounds the yielding banks have to be protected, the velocity of the current diminished in certain places, and the channel held in place by building up or solidifying its sides. The different means employed in this sort of work are described by Captain Hanbury of the Engineer Corps, in a recent report upon the condition of the Missouri River, near Omaha. For causing deposits to take place, and for deflecting the currents in localities that are to be built out, floating brush obstructions have been applied with marked success. The most successful of these is the floating brush dike, made by taking saplings from twenty to thirty feet long, and from four to six or eight inches in diameter, and nailing or fastening to them with wire, scraggy brush of any kind obtainable in the locality. This forms what is known as the 'weed.' Instead of the saplings rope may be used to hold the brush. To one end of this 'weed' is attached an anchor of sufficient weight to hold it in position against the current; to the other a buoy to hold up the down stream end and prevent it from going to the bottom under the pressure of the current against it. These 'weeds' are placed from ten to twenty feet apart, thus forming the floating dike. Their action is to check the current gradually, without producing that scouring effect to which the solid dike gives rise. This done, a portion of the material which is rolling along the bottom or being carried down in suspension is deposited, and causes a rise in the bed of the river, which changes its channel to the direction desired. The rapidity with which these deposits take place is truly wonderful. One season is often sufficient to raise the river bed up to the limits of ordinary high water.

"Another form of obstruction that has been tried with success is the willow curtain. This, as its name indicates, is made of willows about an inch in diameter or larger, fastened parallel with each other, and from six to eight inches apart, by means of wire. The curtains can be made of any desired width and length. They are anchored in position by weights attached at intervals along the lower edge, and held in an upright or inclined position in the water by floats made fast to the upper edge. Their action is similar to that of the 'weeds.'

"Another form that has been experimented with, and which bids fair to give good results, is a screen made totally of wire, something after the fashion of a seine. It is anchored and buoyed like the willow curtain. The rootlets and small vegetable fibers that float in large quantities in the water accumulate upon the wires, and form obstructions sufficient to check the velocity of the current."

Application of the above experience.

Here we find remarkably favorable results produced in a deep and rapid river, by methods the most economical and safe in their application. It only requires an intelligent study of our circumstances here to apply some one of these contrivances successfully in each case.

For instance. I do not doubt that the Yuba River, now coursing down the line of the north levee, for about three miles of its length, transporting a great volume of sediment past it daily, can be made to deposit this load where it now threatens erosion, by the use of some such means as the brush curtain applied on the Missouri River. Thus, by checking the current at short intervals by these screens, we would build up a levee strong enough to resist all attacks of the floods—for there is no reason why it should not be a thousand feet through on the base, all deposited by the water itself up to the height of the flood line.

These screens are really open work brush dams, and act as has been described before of such works.

There are circumstances, then, under which pervious brush dams may be used to advantage on the Yuba and Bear Rivers, but to store the great mass of sands that are to come down these rivers, even during the first few years of this work, more substantial structures will be required of brush and gravel, and in the future the great mass of detritus must be held by rock dams between the foothills as before described; unless, indeed, it is proposed to let these sands spread over large areas of land as yet uninjured.

And here I remark that the application of this idea of causing the waters to deposit their burden of detritus by opposing at short intervals permeable obstructions to their flow, is almost illimitable.

By the use of heavy brush curtains trailing in the waters, and swung from shore to shore in

the wider parts of the river cañons by means of cables, it would be possible to arrest the great mass of sands between a series of low rock brush rapids, and thus fill up the whole cañon for a number of miles in length at once, without the use of any heavy dams at all.

The cost of the work would probably be excessive, however, and the plan is only mentioned to show to what extent the possibilities in this matter reach. It is evident that sediment-bearing waters may be made to deposit their load under any ordinary circumstances; but it is also clear that if the waters are to continue to run over the deposit, some more stable obstructions must be introduced to prevent subsequent erosion. Hence the introduction of the rock and brush riffles spoken of above.

Our work not an experiment in the popular sense.

It is well in this connection, also, to allude to one more point. It has been said that this work is altogether experimental. This assertion is not correct.

Nothing is more certain than that the flow of these sands can be arrested before they reach the main rivers; the engineering principles upon which we are to work are well understood, and their operation proven.

But, under the particular circumstances which we have, there is a question as to how the object can be most cheaply accomplished.

To this extent the work is experimental, and if carried forward intelligently it cannot but result in showing, after the first year or two of trial, wherein economies may be practiced and the object attained at less cost, as all river works have before it.

SPECIFICATIONS FOR BRUSH WORKS.

On this day I hand you specifications for brush dams on the Yuba and Bear Rivers.

They are drawn for heavy dams, intended to become rapidly impermeable as the muddy water flows over them, and upon the principle heretofore laid down. In my opinion, it will be necessary to put such structures, at least, across all open channels where the force of the current at flood time is to be resisted, and it is intended to cause a deposit for the full width of the stream; in other words to store the detritus above the dam.

Where the line of a dam is located through a heavy growth of brushwood, or young timber, the character of the structure may be changed so as to effect a material saving in construction.

A belt of such timber left standing forms a dam for our purposes itself, and taken as the framework of a permeable dam, this kind of a structure might be put up through such a belt at a very moderate cost, in line with the heavier dams across the open channels.

I do not attempt to draw specifications for this class of work at this time. Indeed, so much will depend upon the exact character of the growth itself, that it will be necessary to examine each line in detail before any such attempt can be made to advantage.

When the lines of the proposed dams can be gone over after the water has fallen somewhat more, I will, if desired, make specifications as are required.

Difficulty of describing river works in detail before construction.

Here let me call attention to the difficulty of drawing a description of such works sufficiently in detail upon which to contract.

The best laid plans for this class of river works have almost always to be changed to suit the peculiar circumstances and conditions found or developed during the course of operations.

Frequently it may cost near as much to make the examinations necessary upon which to base specifications for such works as it would cost to do the work itself under management, where there was latitude for the exercise of discretion on the part of the engineer in charge.

And I desire to be understood now as saying that much must be left to the judgment of the engineer in charge, who, as the work progresses, should fit its details to the conditions presented.

For this reason it would be much better if this work could be done by day labor, and not under contract; though it is possible that the objections to this arrangement from other causes would more than counterbalance the advantages presented upon the score just spoken of. And yet I cannot see how the thousand and one little jobs of work, which I may with truth call *stitches in time*, that will have to be carried forward by your Engineer, can be done by contract. It will cost as much to advertise some of them as it will to do them.

Very respectfully, your obedient servant,

WM. HAM. HALL,
State Engineer.

From the foregoing reports it will be observed that in consonance with the law under which we are acting, the sole object of our endeavors is directed to promoting drainage, and while some of the operations may, to a secondary extent, produce results apparently at variance with this theory, yet, in every instance, the primary object

has been, and is, to expend the funds intrusted to our management, in such manner only as will further the end in view, viz.: to so improve the regimen of the main artery, the Sacramento River, that it may safely, and with certainty, conduct the waters of its tributaries to the great outlet which nature has provided. As a sequence of this result, the navigation of the Sacramento will doubtless be improved, the lands adjacent to the stream will gain protection, the debris from the mines will be arrested, and many minor advantages gained, but they are all secondary, and dependent upon the one primary object.

It will also be observed that two general classes of works are recommended, the first being preventive, and having for its object the restraining and impounding the sands of the tributaries, and thus preventing their entrance into the navigable waters of the main streams ; the second, remedial, and intended to improve the channels of the streams as flood-carrying and navigable channels. In pursuance of the first of these objects, and for the purpose of arresting the flow of detritus from the mines, we have caused to be constructed permeable brush dams across the Yuba and Bear Rivers.

That upon the Yuba is located, approximately, seven and one-half miles above Marysville, is nine thousand six hundred feet in length, and has an average height of seven feet.

That upon Bear River is located at Johnson's Old Crossing, about three miles above Wheatland, is six thousand feet in length, and has an average height of six (6) feet.

The following specifications will serve to illustrate the mode of construction of those dams, it being premised that the one on the Yuba is located at what is designated as Site Number Two (2), and not at the point first proposed, and that the specifications were somewhat modified, both before the work began and during its progress. For an account of these modifications, and the reason therefor, we refer to the report of the State Engineer, which will be submitted to you.

SPECIFICATIONS

FOR A BRUSH DAM ON THE YUBA RIVER, DRAWN FOR PROPOSED LINES FOR DAM NUMBER ONE.

DAM EIGHT FEET HIGH.

Cross section of dam, exclusive of backing	400 square feet.

EXCAVATION—

Pit at heel of dam	64
Pit at toe of dam	130
	194

Solid contents of the timber and brush in the dam, 70 per cent.	10.37 cu. yds. (2.19 cords) per 1 foot of dam.
Ballast in dam, 30 per cent.	4.44 cu. yds. per 1 ft. of dam.
Gravel backing	2.00 cu. yds. per 1 ft. of dam.
Excavation	7.19 cu. yds. per 1 ft. of dam.

TREES REQUIRED PER ONE FOOT OF DAM.

1.35 trees, 8 inches in diameter, 33 feet long.
1.35 trees, 8 inches in diameter, 34 feet long.
1.35 trees, 8 inches in diameter, 35 feet long.
1.35 trees, 8 inches in diameter, 36 feet long.
3.60 trees, 6 inches in diameter, 17 feet long.
3.60 trees, 6 inches in diameter, 16 feet long.
3.60 trees, 6 inches in diameter, 15 feet long.
3.60 trees, 6 inches in diameter, 14 feet long.
4.32 trees, 7½ inches in diameter, 17 feet long.
1.44 trees, 7½ inches in diameter, 20 feet long.
1.44 trees, 7½ inches in diameter, 23 feet long.
1.54 trees, 7 inches in diameter, 33 feet long.
1.54 trees, 7 inches in diameter, 30 feet long.
1.54 trees, 7 inches in diameter, 28 feet long.
1.54 trees, 7 inches in diameter, 26 feet long.
1.54 trees, 7 inches in diameter, 24 feet long.

34.70

SITE AND CHARACTER OF THE DAM.

1. The site of the proposed dam is on the Yuba River, 9.28 miles in a direct course above the county bridge, across that stream at Marysville, and in a line immediately across the general direction of the river from the long rocky point which puts out from the north highland shore into the sand and gravel covered bottoms, now occupied by the waters as a flood channel.

2. The alignment of the work designated "site of the proposed dam No. 1," as determined upon preliminarily, is shown on the detail map of Yuba River, to be seen in the office of the State Engineer, or the office of the Board of Directors of the Drainage District in the State Capitol building, and the position of this line is marked at each end on the ground by a redwood stake, 6x6 inches square, to which is attached a small pole and flag; the post being marked with the brand of the State Engineer Department (S. E. D., 1.).

3. In the direct course the distance across the high-water river bed between these posts is about 4,800 feet. The sands of the high-water channel occupy about 4,600 feet of this distance, and vary but little from a level plane in their profile along this line, except at several points where channels three to five feet in depth are cut down. At their low stage the waters run in these channels, or one of them, to a depth of one to two feet. The bottom of these channels are of gravel, and the intervening plane, composed of sand and gravel, is at points covered by a slight growth of timber and brushwood. The northern end of the line is on a bold rocky point; the southern end on a sloping earth bank.

4. It is proposed to construct on the site thus described a dam of brushwood and gravel, to a height of eight feet above the average elevation of the ground's surface, and it is presumed that this dam will range in height from four to twelve above the foundation.

5. Accompanying these specifications will be found a tracing sheet marked, "Plans for the proposed brush dams," exhibiting cross-sectional drawings, with dimensions and quantities of materials (as estimated) in the proposed dam for elevations ranging from six to ten feet, inclusive.

6. From these drawings it will be seen that the structure will consist, in general terms, of close crib-work, composed of small trees with the branches and bushy tops for the most part left on, the spaces between the trees and branches being closely packed with gravel and small brushwood. And further, that the upper toe of the structure is heeled in below the surface of the ground with its top on a level therewith, while the main part, which forms the dam proper, rests upon the natural surface adjusted to a level plane.

LONGITUDINAL DISPOSITION OF THE DAM.

7. This dam is to be constructed so that its crest, as represented by the upper edges or corners of all the three butts which end at the top surface throughout the width thereof (up and down stream) and for at least 4,000 feet uninterruptedly of its length, on completion and final acceptance of the work, shall be within four tenths of a foot of one level plane. So that allowances made for settlement must be agreed to by the contractor before and during construction, as the exact circumstances of foundation and character of material are ascertained; and the work must be so done, at the contractor's risk, that the condition, as to elevation of crest, will be present on final completion as aforesaid.

8. On completion and acceptance, also, the down-stream edge of the dam's crest must be in such alignment that it will nowhere depart more than one foot from the straight line forming its ends, and the over-fall face must be on a uniform slope of about forty-five degrees, as shown in the drawings.

9. Each way from the level portion (the position of which will be designated by the resident engineer on commencement of the work) the dam's crest must rise towards the ends thereof on slopes of from two in one hundred to six in one hundred, as may be determined upon by the resident engineer, preserving a level-topped cross section, and ending at an elevation of six (6) feet above the plane of the level portion.

10. According to the shape of the ground surface and character of the material found along the line, the foundation of this structure is to be laid in level benches in depths below the general surface of the adjacent portions of the stream-bed, approximating closely to those shown on the diagram of cross-sections. The exact grade of each bench or division will be determined by the resident engineer before or during the work of construction, when the character of the material and shape of the surface becomes known. Each two adjacent benches in the foundation are to be connected by a slope not in excess of one on ten in degree of inclination, and no bench shall be less than one hundred feet in length, exclusive of any such slope.

CROSS-SECTIONAL DISPOSITION OF THE DAM.

11. When finally completed and accepted as a whole, the crest (as before defined) of this dam shall nowhere vary more than four tenths of a foot from a level plane in any line across it. The trees on the up-stream face of the dam must lie in a plane sloping within five degrees of the inclination which corresponds with a slope of one on two (1 on 2), and its down-stream face (as made up by the butts of the trees in the body of the dam) must lie in a plane sloping within five degrees of that corresponding to a slope of one on one (45°).

12. The plane of the lower apron (as shown by the red line in the cross-sectional drawings) in each longitudinal bench-division of the work must be within two tenths of a foot of the

grade set for it, which will be even with the average elevation, as at first found, of the ground's surface adjacent to its lower edge.

FOUNDATION OF THE DAM.

13. Upon making a profile survey and drawing of the site of the dam, the resident engineer will lay out the work in divisions, each of which shall be at least one hundred feet in length, and subsequently the foundation is to be laid down in each of such divisions as a whole, or in subdivisions not less than one hundred nor more than two hundred feet in length, as may be deemed best by the engineer.

EXCAVATION.

14. For at least half of such division or subdivision, as the case may be, the excavation is to be made complete to the determined sub-grade before the laying of the brush is commenced within the same.

15. The work of excavation may be carried on by any method to suit the contractor's convenience. Spare material must not be left in a continuous ridge below the apron, but such ridge, if made in the process of excavation, must be broken through at one hundred feet intervals, and free escape ways must be provided for the water on a level with the top of the adjacent portion of the apron for at least half of every subdivision of the work.

16. The depth and width of the excavations for a dam of each sized section probable are shown on the diagrams heretofore referred to, and these dimensions are to be closely adhered to in each instance, on the average throughout each division of the work, except as provided in next paragraph.

17. In cases where the material found in excavation is not such as, in the opinion of the engineer in charge, it is desirable to build on, the contractor will be required to continue excavation, if necessary so to do, to as much as twice the depth originally designated on the profile and diagrams of cross-sections, and build the structure thereon at the contract rates for the work; *provided*, that no excavation shall ever exceed six feet in depth on the average for any one hundred feet of foundation.

18. It being understood that only in case of such material as soft slime or "slickens," and quick-sand being encountered or other substances which would render the foundation unsafe in the opinion of the engineer in charge, are the excavations to be made deeper than those originally set out on the profile when the grades are first established.

19. In case materials of such consistency that the foundation pits cannot be maintained after excavation are encountered, then, in the discretion of the engineer in charge, the excavations may proceed in smaller subdivisions at a time than those heretofore designated, which shall be immediately filled with brush and gravel to such an extent and in such manner as the engineer in charge may direct.

20. In general, the sub-grade of the structure, being the ground surface upon which the structure is to rest, is to be disposed as shown in the cross sectional drawings, and the longitudinal profile hereafter to be made as aforesaid.

THE STRUCTURE.

21. Upon the ground surface thus shaped and prepared, the structure is to be built in the following manner:

22. The lower apron laid entirely beneath the average plane of the ground's surface, is to be first built in each division or subdivision of the work.

23. It is to be composed of small trees, varying from twenty-five to thirty feet in length in the averaged sized structure (and of greater or less length, as shown in the drawings for the larger and smaller cross sections), and four to eight inches in thickness of butt, laid close together lengthways up and down stream, in horizontal layers, separated by smaller poles placed at right angles to the direction of the trees in the layers, the whole to be consolidated and filled in with small brush loaded and incorporated with gravel to the extent of thirty per cent. in bulk of the structure.

24. The poles of each set are to be spiked solidly down upon the tree trunks below, and the trees of each layer are to be solidly spiked down to the poles upon which they rest. Tree nails of hard wood may be used in this fastening, or iron spikes of sufficient length to take at least two and a half inch hold may be used.

25. The upper apron, laid partially below and partially above the natural surface of the ground, is to be next built, in each division or subdivision of the work. As shown in the sectional drawings, this apron rests partly on the lower apron and partly on the ground, up stream from it.

26. It is to be composed of the same class of materials as the lower apron, and laid in the following manner: Small trees or trunks of trees, varying from fifteen to twenty-five feet in length in the average sized structure (and of greater or less length, as shown in the drawings for larger and smaller sections), and six to nine inches thickness of butt—are to be laid close together lengthways up and down stream, in layers sloping downwards and retreating up stream, the butts exposed on the down stream edge of each layer, covered or buried at the up stream edge, and for the greater portion of their length. Alternating with these layers of trees, poles of smaller diameter are to be laid, crossing the trees at right angles. The spaces are to be

filled in with small brush loaded and incorporated with gravel to the extent of thirty per cent. of the bulk of the structure.

27. The poles of each set are to be solidly spiked down upon the tree trunks below, and the trees of each layer are to be solidly spiked down to the poles upon which they rest. Tree nails of hard wood may be used in this fastening, or iron spikes of sufficient length to take at least a four inch hold may be used.

THE DAM PROPER.

28. The dam, resting partially upon the up stream edge of the upper apron, partially upon the ground's surface next above, and partially in a pit at the upper edge, is to be next built in each division or subdivision of the work.

29. Its composition and the arrangement of its parts is similar to that of the upper apron. Small trees or trunks of trees fourteen to eighteen feet in length and six to nine inches in diameter of butt, are to be laid close together lengthways up and down stream, in layers sloping downwards, in an up-stream direction, the butts exposed on the down-stream edge of each layer. Alternating with these layers of trees, poles of smaller diameter are to be laid crossing the trees at right angles. The spaces in the layers and between the layers are to be filled in with small brush, loaded and incorporated with gravel to the extent of thirty per cent. of the bulk of the structure. In this manner the dam is to be built up to the intended élevation of its crest; and then trees of larger diameter and thirty to forty feet in length are to be used, as shown in the sectional drawings, with their butts in rows forming the top surface of the dam, their trunks sloping downwards up-stream, on an angle of about one below two, and their tops buried in a pit and incorporated with gravel and brush as in other cases provided.

30. The dimensions of materials in the dam are given for the average sized structures (that eight feet high); larger trees are to be used where the dam is higher, and smaller may be used where it is lower.

GRAVEL BACKING.

31. On the up-stream face of the dam, and on the toe thereof, a bank of gravel is to be placed, as shown in the drawings, in amounts in the different divisions of the work varying with the height of the structure, as follows:

On a 4 foot dam, 1.00 cubic yards of gravel per linear foot.
On a 6 foot dam, 1.50 cubic yards of gravel per linear foot.
On a 8 foot dam, 2.00 cubic yards of gravel per linear foot.
On a 10 foot dam, 2.50 cubic yards of gravel per linear foot.
On a 12 foot dam, 3.00 cubic yards of gravel per linear foot.

STONE BACKING.

32. In the discretion of the Board of Directors a rough stone backing may be substituted for the gravel backing; this point to be determined after opening the bids for the work.

33. In case such stone backing is adopted, then it shall be placed as is the gravel backing, or as directed by the engineer in charge, and the amount of stone used will be about two thirds of those designated for the different heights of dam for a backing of gravel. Special figures in the bids for gravel and for stone will be required, as hereafter provided.

THE ENDS OF THE DAM.

34. At the northern end this dam is to be set in a bench cut in the rock point from which it there springs, in such manner as may be designated by the engineer in charge; *provided*, that the excavation necessary shall not exceed 600 cubic yards in amount.

35. The end of the dam itself is to be thoroughly covered and protected with rough stone, as may be directed by the engineer in charge; *provided*, that the amount of stone necessary shall not exceed 1,200 cubic yards. The character and size of stone shall be same as that for backing, as before specified.

36. The southern end of the dam is to be similarly covered in and protected, and connected with the face of the hill or slope against which it will rest, and the same provisions are to apply.

37. And all concerning this end finish and protection of the dam is to be considered with the proviso that the Board of Directors may adopt whatever method or plans of work they may consider best under the circumstances, and may, for as much as 1,000 feet in length, at the southern end of the work, substitute or append an earthen embankment or levee, protected on the upper face by a rip-rap covering of rough stone, in pieces not less than one cubic foot in length.

END TRAINING WALL.

38. At the southern end of the overfall of the dam, a training wall, built as a groyne to the dam and in a similar manner to the dam itself, is to be carried out from the lower face of the dam to a distance of one hundred feet and returned, parallel to the dam, to the hard bank land, to a distance not exceeding four hundred feet, and this shall form a finish to the apron at that end, and beyond it no apron need be constructed.

39. The connection between the groyne and the dam is to be made as the engineer in charge may direct, as are all connections and finish in detail of the parts.

MISCELLANEOUS PROVISIONS.

40. In the construction of this dam, it will be necessary to turn the waters of the stream from their low-water channel in order to construct therein; and this work is to be done by the contractor at his own risk and expense, without compensation other than provided for in payment for the main work.

41. The brush and trees necessary for the construction of this dam are to be cut off the sand-covered flats adjacent to its site, and the Directors guarantee to the contractor the right to cut and remove the same without compensation for damages or payment for the material; *provided*, that in such cutting and transportation, the contractor constructs all necessary roads and causeways, and openings in fences, etc., and exercises due diligence and care to avoid unnecessary damage: *and further provided*, that the Directors will not be responsible for any damage occasioned by reason of the escape of stock, or the inroads of stock upon crops or pastures which may be occasioned by the openings in fences, made by the contractor, or in any way by the occupation of premises by him.

42. The brush cutting shall be conducted under the direction of the engineer in charge, and in no case shall all of the brush be stripped from the land below the site of the dam; but belts thereof, at least fifty feet in width, shall be left at five hundred feet intervals, and extending across the general direction of the stream so far as it grows.

43. The rock necessary in the construction of this dam shall be quarried half on the north side of the stream from the down stream face of the point against which the dam is to rest, at such point as the engineer in charge may direct, and half on the southern shore of the river, in the rocky point just above the dam site.

44. The Directors guarantee the contractor the right to quarry and remove this rock without compensation for material, or damages under the same provision as heretofore enumerated in the matter of cutting and removing brushwood for the dam.

45. The Directors guarantee to the contractor the right of way for the transportation of all material on such routes as may be reasonably practicable, and on conditions as respects liability for damages, similar to those already inserted in the section concerning brush cutting.

46. All brush cut and all rock quarried in the prosecution of this work, and remaining unused at its completion or forfeiture of contract, is to revert to the Board of Directors, and the contractor is not to lay claim, after the work is done, to any peculiar privileges of right of way, or right to material of any kind other than his plant of tools and appliances which may be removed from the premises.

47. Whenever the word *gravel* is used in these specifications, it is to be taken as meaning the best material of the kind to be found along the line of the structure, or within 500 feet thereof; it shall not contain more than 30 per cent. of sand, and must pass inspection of the engineer in charge.

LAYING OUT AND MEASUREMENT OF WORK.

48. This work is to be staked out by the resident engineer, under the direction of the State Engineer, and is to be carried forward to the satisfaction of the engineers and the Board of Directors of the district.

49. Measurements for works of certain dimensions are given on the exhibits and schedule hereunto appended, and made a part of these specifications as hereafter enumerated. Payment is to be made on such measurements for the standard sizes shown, and for intermediate sizes payment will be made upon dimensions of cross sections proportioned to the height of the dam above the ground line in each case.

50. All extra work of any class, except excavations to depths below the limit heretofore specified (six feet), is to be done at contract prices upon the measurement thereof.

51. Measurement of work is to be agreed to by the contractor and resident engineer upon each division thereof before it is laid in.

52. Work is only to be accepted and approved and taken off the contractor's hands upon the final completion of the entire structure.

53. In case of any undue settling of any part of the dam after the completion of that part, the integrity of the work is to be preserved in such manner as the State Engineer may specify and the Board of Directors may direct, and consequent differences between the contractor and the Board of Directors are to be made by the Directors and in their discretion.

54. The work is to be prosecuted from its two ends simultaneously, and with all due diligence and dispatch, and brought forward in the manner and order directed by the engineer in charge.

AMENDMENTS TO FOREGOING SPECIFICATIONS.

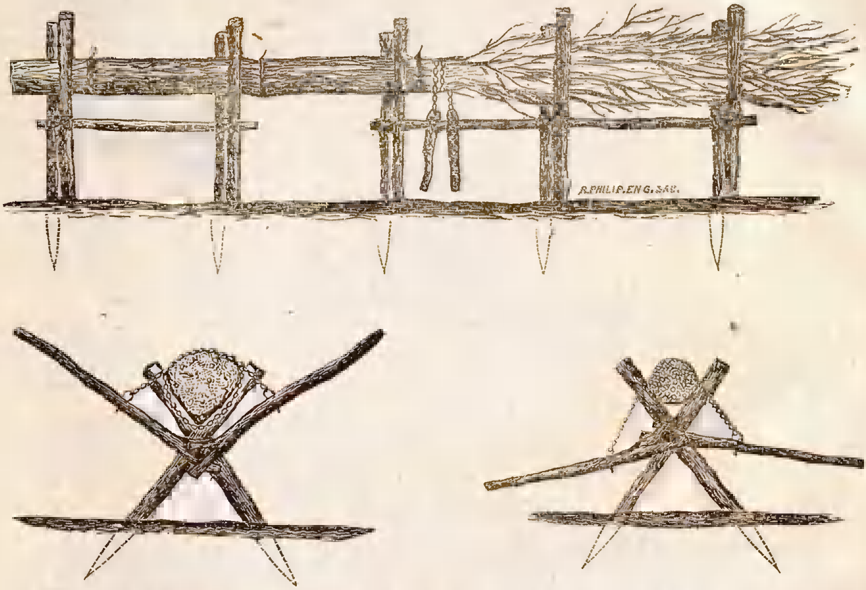
Prepared at request of the Board of Directors, District No. 1, July 6, 1880.

55. The foregoing specifications are to govern the construction of the contemplated dam, except, in case trees of proper size cannot be secured in sufficient number for the purpose within 2,000 feet of site of the work, when, after close examination, the Board of Directors may curtail the dimension of the dam in cross section.

56. And again, should the supply of small trees—as called for in the specifications—to be found within 2,000 feet of the work prove to be insufficient to complete the structure to the dimensions finally determined upon by the Board of Directors, the contractor may substitute bundles or fascines of smaller trees or brush saplings, made and laid under the direction of the engineer in charge.

57. The fascines are to be made where the brush is cut, in lengths proper to substitute for the small trees called for in the specifications; are to be made in presses, as shown in a cut accompanying these specifications, or in some way insuring equally good manufacture; and are to be firmly bound, at four-foot intervals, with No. 16 (Birmingham gauge) iron wire.

FASCINE CONSTRUCTION.



58. These fascines are to be substituted for the trees where designated by the engineer in charge, are to be pegged down and together firmly, and treated in all respects as are the trees in the structure; *provided*, that the top course at the upper edge, and that at the lower edge of the dam's crest, and the course at the foot of the overfall shall be composed entirely of trees of the dimensions and otherwise as at first specified.

BIDS FOR THE WORK.

59. The work to be executed in completing this structure is classified as follows: 1—Excavation for foundation; 2—Brush and timber ballasted; 3—Gravel backing; 4—Stone backing; 5—Stone weighting and protection of ends of the dam; 6—Earthwork embankment or levee at south end of the dam.

60. *Excavation.*—Includes removal and disposal of all material to be handled in preparing a formation for the dam and the auxiliary works.

61. *Brush and timber, ballasted*—Includes the cutting and transportation of brush and timber, the excavation and transportation of gravel for ballast, the laying of these materials, and completion of the structure composed of them as before specified.

62. *Gravel backing*—Includes the excavation, transportation, and depositing of this material as heretofore outlined.

63. *Stone backing*—Includes the stripping and opening of quarries, excavation, transportation, and laying of stone according to specifications and directions.

64. *Stone weighting and protection*—Includes work as provided above under head of "Stone backing."

65. *Earthwork embankments*—Includes the construction of an earthwork levee not over 1,200 feet long at south end of dam, containing about five cubic yards of material per linear foot. The work to be done with scrapers and as directed by the engineer in charge.

Bids are desired for this work as follows:

66. *For the excavation:* Per cubic yard, measured in the pit.

67. *For the brush and timber ballasted:* Per cubic yard, measured in the work (predetermined allowances for settlement not counted in.)

68. *For gravel backing:* Per cubic yard, measured in place on completion.
69. *For stone backing:* Per cubic yard, measured in place on completion.
70. *Stone weighting and protection:* Per cubic yard, measured in place on completion.
71. *Earthwork embankment:* Per cubic yard, measured on completion (predetermined allowances for settlement not counted.)

SPECIFICATIONS FOR THE DAM AT SITE NO. 2, ON THE YUBA RIVER.

These specifications, so far as the composition and construction of the dam are concerned, are substantially the same as those for the dam at site No. 1.

The points of difference are shown in the following synopsis of specifications for the dam at site No. 2.

1. The proposed dam site No. 2 is two (2) miles below site No. 1.
2. The line is marked on the ground similarly to line No. 1, and on the map is shown as "Line of proposed dam No. 2."
3. In the direct course the distance across the high-water channels and intervening flats of the river is about 9,600 feet, and consequently the dam proper will be about this length.

Paragraphs 4 to 31, inclusive, are the same as in specifications for dam at site No. 1.

Paragraphs 32 to 36, inclusive, are omitted.

37. *End finish:* The ends of the dam are to be raised gradually, so that water will not run over its crest within at least 100 feet of the ends proper, and these are to be joined with the natural bank, or with earthwork embankments.

Paragraphs 38 and 39 are the same, with the exception that there must be a training wall at both ends of the dam, at site No. 2.

Paragraphs 40 to 58, inclusive, are the same.

Paragraph 59, leave out "stone backing," and "stone weighting," and change numbering to suit.

Paragraphs 60 to 62, inclusive, the same.

Paragraphs 63 and 64 to be omitted.

Paragraphs 65 to 68, inclusive, the same.

Paragraphs 69 and 70, inclusive, to be omitted.

Paragraph 71, the same.

SPECIFICATIONS FOR A DAM OF BRUSHWOOD AND GRAVEL ON BEAR RIVER.

These specifications are in all respects similar to those for the dam at proposed site at No. 2, on Yuba River, with the exception that the site is described as being on a line directly across the river from a point 200 feet, more or less, above the head of the levee on the north side of what was formerly known as Johnson's Crossing, and the probable length of the dam is about 6,000 feet.

The contracts for the erection of the dams were awarded on August 10th, the one on the Yuba River to Messrs. Rideout & Binney, of Marysville, and that upon Bear River to Messrs. Doane & McBean, of San Francisco.

The cost of the works was somewhat enhanced by the fact that the contractors were, by the terms of their contracts, required to complete the structures within sixty days, the fear of approaching storms precluding greater delay. A variety of causes combined to prevent the completion of either structure within contract time, but fortunately the work was finished before storms intervened.

It is too soon, however, to speak in the light of mature experience of the effects to be produced by these dams. State Engineer Hall, who has made their construction and availability a subject of patient and persistent study, is sanguine as to the results to be experienced, and his theories have the approval of such eminent engineers as Colonel G. H. Mendell, United States Engineer, and Captain James B. Eads, both gentlemen of world-wide celebrity in their profession, and who have, in their capacity as Consulting Engineers, given this work special attention.

Thus far the dams promise all that can be hoped for. They check the flow of water and rid it of the heavier portion of its sand, which has already accumulated to a considerable depth just above the

structures, and the water thus relieved of its surcharged material, is permitted to flow on with its scouring capacity greatly increased.

LEVEE WORK.

The work of constructing levees to confine the waters of the Feather, Yuba, Bear, and Sacramento Rivers within their respective channels, with a view to increase the scouring capacity of those streams during flood periods, has been steadily pushed forward on as large a scale as the funds at command would warrant.

The following table will show the amount and the purposes for which money has been expended:

State Engineer Department—Payroll	$12,262 00
State Engineer Department—Expenses	5,158 87
District Engineer Department—Payroll	7,841 41
District Engineer Department—Expenses	4,086 66
Assessors and Auditors of counties, in District	8,965 99
Advertising	1,025 50
Legal expenses, brush, &c.	863 50
Salaries of Directors and Secretary	2,286 64
Office expenses	50 00
Printing, specifications, stationery, etc.	326 65
Paid for work (per contract)	320,321 18
Total	$363,188 40

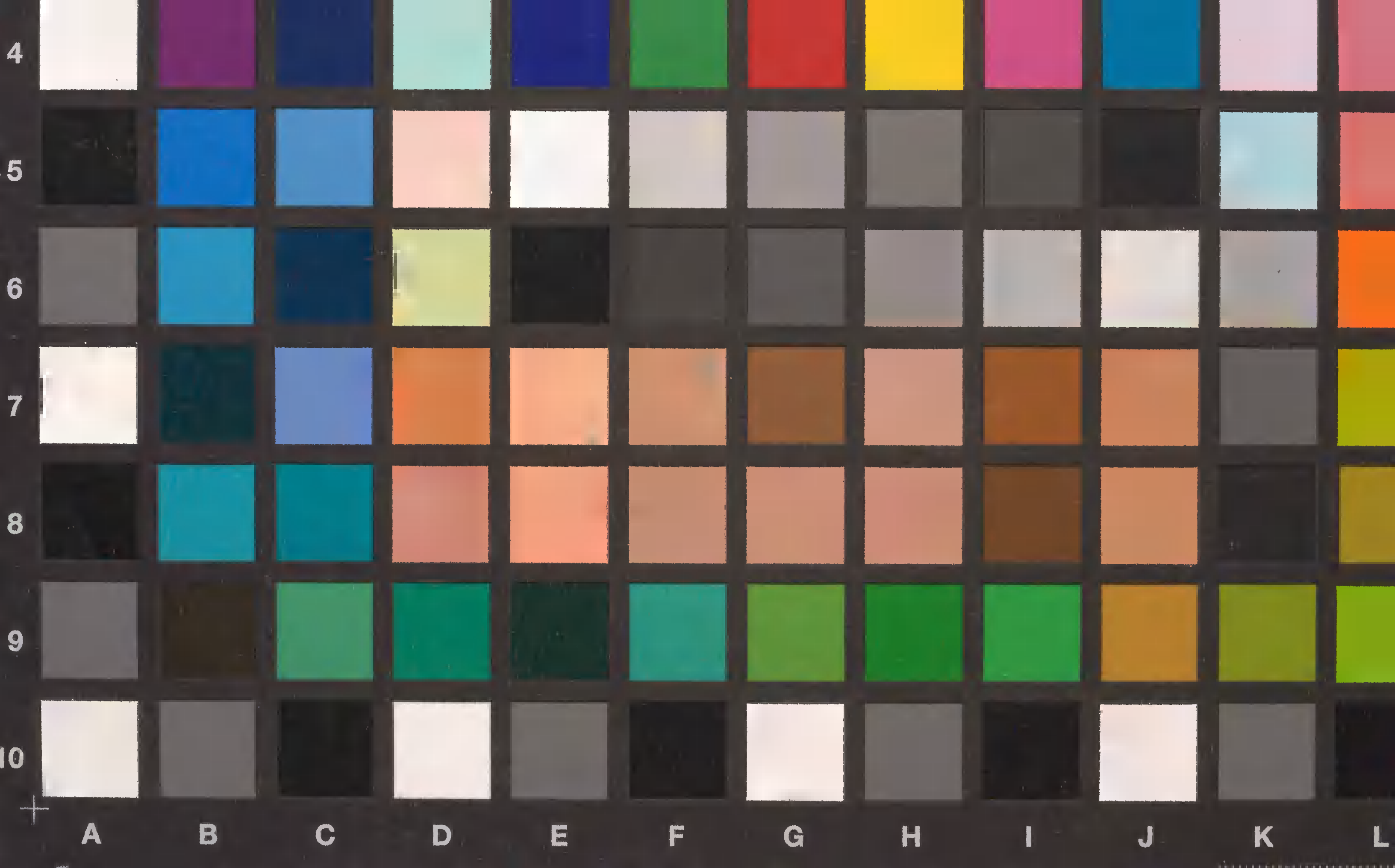
We have commenced suits for condemnation of land to be used for storage of debris above the dams, and material of which said dams are constructed, as provided for in section eleven of the Act to promote drainage, and said suits are now in process of litigation.

CONCLUSION.

Difficult as has been the labor entered upon by the Directors, they feel warranted by experience in declaring that during the progress of their operations they have seen much to encourage the hope of ultimate success. Obstacles that seemed insurmountable, have either disappeared or proven less formidable than was supposed. Many who, at the outset, doubted the feasibility of controlling the large volume of mining debris constantly being sent down from the mountain gulches, of restoring the regimen of the rivers, and teaching those rivers to excavate their own channels, better informed, are yielding to the belief that, by an intelligent and systematic treatment of the whole problem, our navigable waters may be saved to commerce, the industries of the farmer and miner brought into such relations that each may prosper without material injury to the other, and the general welfare be promoted at an expense commensurate with the object to be obtained.

W. H. PARKS,
W. F. KNOX,
NILES SEARLS,
Board of Directors of Drainage District No. 1.

Attest: CHARLES M. COGLAN, Secretary.



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